Measuring Brain Perfusion in the Pediatric Brain

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During the development, brain undergoes the sequential anatomical, functional and organizational changes necessary to support the complex adaptive behavior of a fully mature normal individual. The delineation of developmental changes occurring in different brain regions might provide a means of relating various behavioral phenomena to the maturation of specific brain structures, thereby enhancing the understanding of structure-function relationships in both normal and disease states. One approach to study these modifications has been the measurement of the regional substrate utilization at different ages, or rather of a physical quantity correlated to cerebral metabolism and to the local functional activity, such as the cerebral perfusion. Generally perfusion refers to the blood micro-circulation, or circulation in micro-vessels, and it is usually quantified by the measurement of a hemodynamic parameter, the Cerebral Blood Flow (CBF).

The measurement of perfusion has been given by several techniques, such as positron emission tomography (PET), single photon emission computed tomography (SPECT) or dynamic CT. Depending on the type of used radiotracer, these techniques could provide different measurements as the metabolic rate of glucose or oxygen consumption. Since the principal brain substrates for energy production are glucose and oxygen, the determination of their regional values would provide a measure of the local energy requirement for functional activity, indirectly bounded to cerebral perfusion. All these techniques are expensive and require the use of a compound labeled with positron-emitting isotopes or the use of ionizing radiation. The involvement of radiation exposure makes these methods not appropriate for pediatric use.

A variety of techniques have been developed to measure directly cerebral perfusion using Magnetic Resonance Imaging. All these methods use a contrast agent that can be exogenous or endogenous. In the first case, perfusion weighted images have been obtained with the infusion of a bolus of a paramagnetic substance, like a gadolinium chelate, modelling the transport properties of blood and its exchange mechanisms with tissue (Dynamic Susceptibility Contrast, DSC, technique). Alternatively, blood flow can also be measured by means of the Arterial Spin Labeling (ASL) technique, which uses arterial water as a diffusible tracer. The method's underlying principle is to magnetically label arterial spins (by continuous or pulsed magnetization inversion at the level of the neck) and to subtract this signal from the one obtained in a control scan performed without labeling. In this way, it is possible to achieve perfusion maps without using ionizing radiation or radioactive isotopes or exogenous paramagnetic tracer compound. Thus, Arterial Spin Labeling provides an absolute non-invasive way to measure quantitatively cerebral perfusion and it is ideally suited to measure cerebral blood flow in the pediatric population, because it is entirely noninvasive and provides improved image quality due to normally increased blood flow and water content of the child brain. With ASL techniques it has become possible to evaluate the changing perfusion patterns accompanying normal brain development and to measure the normal CBF brain values with the MR approach previously evaluated only with PET and SPECT techniques.

Moreover CBF represents an important physiologic parameter for the diagnosis and management of childhood brain disorders. To date disease data on pediatric brain perfusion remain sparse due to the lack of suitable techniques for CBF measurement. ASL technique has been demonstrated to provide reproducible and reliable quantitative CBF measurements in various cerebrovascular and psychiatric disorders in adults. Pediatric perfusion imaging based on ASL may provide unique advantages and can be safely assessed in a wide range both of age groups, including adolescents, children, neonates, and even fetuses and both in various paediatric pathologic conditions. In particular we will analyze the feasibility of using ASL perfusion MR imaging, its power and pitfalls in studying of risk conditions in cerebrovascular diseases, in detecting ictal alteration in epilepsy, in underlying cerebral deficits in cortical malformations and perinatal injury, in revealing abnormalities in some metabolic diseases.

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